

The Uredo-stage of *Gymnosporangium*.

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(WITH PLATE XVII.)

In the *Botanische Zeitung* for June 22, 1888, there appeared a paper by Kienitz-Gerloff entitled, "Die Gonidien von *Gymnosporangium clavariæforme*," in which he describes the presence of two forms of spores in the gelatinous fruit mass of that fungus. Although both are two-celled and of about the same size, they may, he says, be easily distinguished. Those found on the inside of the spore mass are symmetrical, having thin hyaline walls and finely granular contents, while on the other hand the spores more generally present on the outside are not symmetrical, the upper cell being much blunter than the lower one. Their walls are dark brown and more than twice as thick as those of the first form, and their contents are not granular. It is in their method of germination, however, that he sees the most important distinction. The thick-walled spores always send out promycelia of the form which is characteristic of teleutospores. In the thin-walled spores it is entirely different. In these he observed two cases where the end of the spore grew out in a tube, the contents of which did not divide up into cells and bear sporidia, but remained unbroken, resembling in this the method of germination characteristic of uredospores. He also noticed a singular fact, that, instead of the endospore penetrating the exospore as is usual, the whole end of the spore grew out without rupturing the exospore.

From their general dissimilarity in shape and structure, and from their peculiar method of germination, he concludes that these thin-walled spores represent the hitherto unknown uredosporic form of *G. clavariæforme*. Were their morphological characters and the method of germination constant, it would be quite possible that the thin-walled spores might represent what he claims. As the uredosporic form has not before been recognized in any of the *Gymnosporangia*, it seems highly desirable that the view advanced by Kienitz-Gerloff should be tested by an examination of American spec-

imens. That there are two forms of spores in *G. clavariæforme* and also in other species has been known for a long time. Among the more important references are those of Oersted,¹ who figures both kinds of spores in the case of *G. clavariæforme*, of Rees,² in *G. fuscum* and *G. conicum*, of Körnicke,³ and also of Farlow,⁴ and further search would doubtless show other references. Although, as I have just said, the existence of two forms of spores was well known to writers before Kienitz-Gerloff, no particular significance was attached to the fact and they were both considered as forms of teleutospore produced by difference in exposure or time of development.

That the conditions of my work might be as nearly as possible like those of Kienitz-Gerloff, and the results readily compared with his, I took *G. clavariæforme*, the species used by him in his investigation. As it is quite common on the *Juniperus communis* in the neighborhood of Boston, I had no difficulty in getting all the material I wanted. That which I used was obtained from Saugus through the kindness of Mr. Seymour. It was collected on the 11th of April, and being at that time still young the spore masses had scarcely appeared on the bark of the Juniper, but it was easily ripened when kept for a short time under a bell-glass in a moist atmosphere. At the time the first observations were made the young spore-masses were only slightly convex and had not swelled to the conical form attained at maturity. At this stage sections across the spore-mass show that all the spores resemble each other closely, being long and fusiform, and no distinction can be made between the blunt thick-walled and the acute thin-walled spores.

When mature differences in the spores are seen. One kind, which is found in the inner portion of the spore-mass, is composed of two acutely conical cells which are joined at their bases, making a long, symmetrical, fusiform, or lanceolate spore (fig. 1); the other is commonly met with nearer to the periphery and consists, like the first, of two cells, but is not symmetrical, the upper cell being quite blunt and rounded off, thus making the spore clavate in form (fig. 2), as is described by Kienitz-Gerloff. Both forms are of about the same size; the clavate variety being perhaps a little shorter in proportion to its width than the other; and both

¹Bull. Acad. Roy. Sci. Copenhagen, 1867, Plates III and IV, figs. 3 and 7.

²Die Rostpilzformen der deutschen Coniferen, pp. 17 and 26, 1869.

³Hedwigia, xvi. 27, 1877.

⁴The Gymnosporangia of the U. S., 1880.

have long pedicels which are quite distinct when young, but which tend to gelatinize on the edges as they grow older, especially in the case of the fusiform spores. The thickness of the wall averages about the same in all the spores with the exception of those on the very outside. There it is usually somewhat thicker than in the others (fig. 3) and generally of a smoky-brown color. The contents are alike in both varieties, and in no way different from those of the normal *Gymnosporangium* teleutospore, consisting chiefly of a more or less granular mass, in which may be one or more orange oil-like globules and a number of vacuoles. Neither the shape nor distribution of the spores above described is definitely marked, one form gradually passing into the other, with all gradations from the most symmetrically acute variety to the more irregular obtuse one.

In order to see if, as Kienitz-Gerloff maintained, the acute spores germinated differently from the obtuse ones, I took a considerable number of both forms and studied their method of germination under like conditions.

When removed to a glass slide and kept moist with a little water, in a few hours the spores, whether acute or obtuse, produced in the region of the septum from one to three—occasionally four—promycelia of the form typical in this genus, that is, composed of short cells which produce short sterigmata-bearing sporidia (fig. 4). In some cases the sterigmata grew out to an indefinite and often considerable length without producing sporidia. If supplied abundantly with water it not unfrequently happened that, instead of ordinary promycelia, the germinal tubes grew out to a great length (fig. 5), fifteen or sixteen times the length of the spore, and the contents did not divide up, but remained continuous throughout without producing sporidia. When the spores are kept only slightly damp another peculiarity may be noticed. Instead of growing out into promycelia the germinal tubes push out a little distance into short thick filaments and then divide into four or five stout oblong cells which soon fall apart (fig. 6). Subsequently the cells which have become thus separated grow out at one or more of the angles into hyphæ. An appearance resembling such as has been described has also been noticed by Cramer⁵ in the case of *G. fuscum*. The process may be still further simplified. In some cases the germinal tubes protrude a very short distance, not producing promycelia or a filament of any kind, but only

⁵Oeber den Gitterrost der Birnbaunil, etc., Schweiz, landwirth Zeit, 1876.

small bud-like cells as is seen in fig 7. Very soon these buds become separated from the spore, and after a time send out tubes, like those which come from the sporidia when they germinate. This method is seldom found among the spores on the outside, but occurs chiefly in those in the inner part of the spore-mass.

In the forms of germination already considered, it will be seen from the accompanying figures and descriptions that the promycelia arose from the region of the septum in all cases, no matter whether the spore was obtuse or acute, or, in other words, whether it was what Kienitz-Gerloff calls a teleutospore or a uredospore. We come now to other forms of germination, where the germinal tube arises from the apex of the spore instead of from the region of the septum. This method of germination was found beyond a doubt in both the acute and obtuse forms, though more frequently in the latter. In fig. 8 a spore which is clearly of the acute form is represented germinating by the end, while in fig. 9 one of the obtuse kind is shown behaving in a similar manner. This form of germination of the obtuse spores was apparently not seen by Kienitz-Gerloff. In some cases where germinal tubes were produced from the end of the spore promycelia were also found arising from the region of the septum.

The terminal promycelia grew in all respects like the others, and, with few exceptions, they all bore sporidia. No cases were seen where the germinal tubes grew out to any very great length even when the spores had been kept in an excess of water. In one case, where the spores were only kept damp, a terminal promycelium was noticed, which broke up in the same way as those arising from the septum under similar conditions (fig. 10). On two occasions germinal tubes were seen to arise from the fixed end of the spore, very near the point of attachment of the pedicel, but, except for their point of origin, the promycelia were normal.

If we now compare the results of my observations with those of Kienitz-Gerloff, it will be seen that the latter are not sufficient to warrant the conclusions which he drew from them. From both his observations and my own it is plain that the obtuse spores borne on the outside of the spore-masses are teleutospores, since, on germinating, they produce the characteristic promycelia. Apparently Kienitz-Gerloff is of the opinion that the promycelia are always produced at the septum. I have shown, however, that, although

this is the rule, it is not unusual to find the promycelia produced at the apex of the spore. Furthermore, the statement that the obtuse spores are teleutospores is not invalidated by the fact that under certain conditions the germinal tubes do not form the ordinary promycelia with sporidia, but break up into separate cells or even drop away from the spore in the shape of bud-like cells before they have developed into a filament of any kind. With regard to the fusiform spores Kienitz-Gerloff's statement is that they bear germinal tubes, which, in growing out into filaments, do not form proper promycelia with sporidia. But my observations, although they agree with those of Kienitz-Gerloff in showing that terminal germinations are occasionally to be found in the fusiform spores, yet, in the majority of cases, they germinate like the obtuse spores and bear normal promycelia and sporidia at the septum.

Since then it is the fact, as shown by these notes and the accompanying figures, that, in their mode of germination, both the obtuse and fusiform spores bear the promycelia characteristic of teleutospores, we must conclude that, if the obtuse spores are teleutospores, the fusiform spores are also teleutospores. The only ground for supposing that the latter are uredospores is the statement of Kienitz-Gerloff that they do not produce promycelia but rather the tubes found in uredosporic germination, and I have shown that this statement is erroneous, and that what he considers to be the constant form of germination in the case of the fusiform spores is really only an exceptional form of germination, which is also to be seen at times in the obtuse spores with regard to whose teleutosporic nature all writers agree. We must conclude that both the obtuse and fusiform spores are teleutospores in spite of their differences in size and shape. As already remarked *G. clavariæforme* is not the only species in which two forms of teleutospores are known, and for further information on this point one should consult the paper by Dietel in *Hedwigia*, 1889, p. 99. The mode of germination of teleutospores of *Gymnosporangia* is subject to a good many modifications, depending, in part at least, on the variations in the amount of moisture to which they are subjected. The modifications mentioned above, as I am informed by Prof. Farlow, at whose suggestion I undertook the examination of the subject, have been frequently seen by those who have studied this genus, although but little has been said about them in print.

EXPLANATION OF PLATE XVII.—Fig. 1. Typical fusiform spore.

Fig. 2. Typical clavate spore.

Fig. 3. Thick-walled clavate spore of the form found on very outside of the spore mass.

Fig. 4. Showing normal method of germination.

Fig. 5. Method of germination of spores in an excess of water.

Fig. 6. Method of germination of spores when damp.

Fig. 7. Simplified method of same.

Fig. 8. Fusiform spore germinating by the end.

Fig. 9. Clavate spore germinating in a similar manner.

Fig. 10. Terminal germination brought about by same conditions as in 6 and 7.

All these figures are magnified 410 diam. and then reduced one-third, except Fig. 5, which is magnified 250 diam.

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Observations on the temperature of trees.

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(WITH PLATE XVIII.)

During the winter and spring of 1889 experiments were conducted upon the temperatures of trees, and the following preliminary notice of some of the results obtained is given. A number of questions have arisen in the course of the experiments which will require some time to solve, and as these will have to be postponed till the next winter, it is thought best to lay the facts gained so far before those interested in these problems, and reserve the remainder for further consideration. As far as could be ascertained very few data have been collected upon the subject, and the observations are recorded, as they may possibly be of use in the future.

The experiments were conducted in the following manner: Holes one-half inch in diameter were bored into the trees at equal heights from the ground. The thermometers used were Centigrade, and were carefully compared with each other to detect any variation in graduation. The thermometers were inserted in the borings so that the base of the bulb came in contact with the wood; the space about the thermometer being packed tightly with cotton-wool.